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BIOGRAPHICAL NOTICE

OF

SIR WILLIAM SIEMENS, D.C.L., LL.D., F.R.S.

BY

GEORGE W. MAYNARD.

A PAPER READ BEFORE THE AMERICAN INSTITUTE OF MINING
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BIOGRAPHICAL NOTICE OF SIR C. W. SIEMENS,
D.C.L., LL.D., F.R.S.

BY GEORGE W. MAYNARD, NEW YORK CITY.

IN the death of Sir William Siemens, the Institute loses its most distinguished honorary member, one who, without exaggeration, may be ranked among the greatest men of the century. In justification of this claim, I quote in part the words of two other men eminent in the walks of science.

Professor Huxley, addressing the Royal Society, spoke of Siemens as "a marked example of vast energy, large scientific acquirements, and intellectual power of a high order," and as one "who had no superior in fertility and ingenuity of invention, while hardly any living man so thoroughly combined an extensive knowledge of scientific principles with the power of applying them in a commercially successful manner. The value of his numerous inventions must be measured, not merely by the extent to which they have increased the wealth and convenience of mankind, but by the favorable reaction on the progress of pure science which they, like all such inventions, have exerted, and will continually exert."

Dr. Wedding, in his address before the *Verein zur Beförderung des Gewerbefleißes in Preussen*, speaks of Siemens as being "so fortunate as to combine German erudition with British activity in such a manner that both nations, German as well as English, were equally proud of him; and, now that his rich life is ended, regret is expressed on both shores of the North Sea, first by the Germans that his entire life had not been spent in Germany, and his powers dedicated to Germany, and by the English that he was not born a Briton."

Germany may well be proud of being the birth-place, not only of such a man, but of such a family; for where in history shall we find in a single family such a wide range of knowledge so successfully applied to the arts? The least distinguished name in the following list has added to the world's knowledge enough to satisfy the desire for fame of any ordinary man. This constellation is made up of:

Carl Wilhelm Siemens,
 Ernst Werner Siemens,
 Carl Heinrich Siemens,
 Friedrich Siemens,
 Georg Siemens, and
 Ludwig Siemens.

For the information contained in the present brief memoir, I am largely indebted to various published accounts. The most complete life which I have found is that published by Mr. W. T. Jeans in *The Creators of the Age of Steel*. I have also drawn information from Mr. J. S. Jeans' obituary notice in the *Journal of the Iron and Steel Institute*.

For what his family pronounces the most accurate sketch of our distinguished fellow-member's early life, I am indebted to the address of Dr. Wedding above referred to, kindly furnished me by Mr. Wilhelm Siemens, son of Dr. Werner Siemens, of Berlin.

Carl Wilhelm Siemens was born at Lenthe in Hanover, April 4th, 1823, and died in London, November, 1883. He was a son of one of the village officials. His first school-training was in the Catharineum at Lübeck, followed by a course at the Commercial School in Magdeburg.

In Lübeck, the German guild-system was in full force; and he repeatedly referred to it in after-life. "When a boy at school," he says, "I was living under the full vigor of the old guild-system. In going through the streets of Lübeck I saw 'Carpenters' Arms,' 'Tailors' Arms,' 'Goldsmiths' Arms,' and 'Blacksmiths' Arms.' These were lodging-houses, where every journeyman belonging to that trade or craft had to stop if he came into town. In commencing his career, he had to be bound as an apprentice for three or four years; and the master, on taking an apprentice, had to enter into an engagement to teach him the art and mystery (which meant the science) of his trade. Before the young man could leave his state of apprenticeship he had to pass a certain examination; he had to produce his *Gesellen-stück*, or journey-piece of work; and if that was found satisfactory, he was pronounced a journeyman. He had then to travel for four years from place to place, not being allowed to remain any longer than four months under any one master. He had to go from city to city, and thus pick up knowledge in the best way that could have been devised in those days. Then, after he had completed his time of travel, on coming back to his native city, he could not settle as a master in his trade until he had produced his

Meister-stück, or master-piece. These master-pieces in the trade were frequently works of art in every sense of the word. They were, in blacksmithing, the most splendid pieces of armory. In every trade, and in clocks above all others, great skill was displayed in their production. These were examined by the Masters' Committee of the guild, and upon approval were exposed at the Arms of the trade for a certain time, after which the journeyman was pronounced a master. He was then allowed to marry, provided he had made choice of a woman of unimpeachable character. These rules would hardly suit the taste of the present day; but still there was a great deal of good in those old guild practices."

Before Siemens was nineteen years old he went to Göttingen. Here, by his "iron industry," as Wedding puts it, he filled up the gaps of his school-training. Here, under Wöhler, he first got that insight into chemical laws which laid the foundation for his metallurgical knowledge, and here began to develop in him that wonderful thirst for discovery which abundant success never quenched.

Our interest in the beginnings of notable men is frequently greater than in their later achievements, after they have already become great; and I think there are few more interesting histories than that of Siemens, as related by himself in his Inaugural Address before the Midland Institute at Birmingham. Though it has probably been referred to in nearly all of the sketches of his life, I venture to think it will prove of sufficient interest to give it in its entirety here, because he always regarded the period to which it refers as the turning-point in his life.

"At that time (1841), that form of energy known as the electric current was nothing more than the philosopher's delight. Its first practical application might be traced to the town of Birmingham, where Mr. George Elkington, utilizing the discoveries of Davy, Faraday and Jacobi, established a practical process of electroplating in 1842.

"It affords me great satisfaction to be able to state that I had something to do with that first practical application of electricity; for in March of the following year (1843), I presented myself before Mr. Elkington with an improvement of his process, which he adopted, and, in so doing, gave me my first start in practical life. When the electrottype-process first became known it excited a very general interest; and although I was only a young student at Göttingen, under twenty years of age, who had just entered upon his practical career as a mechanical engineer, I joined my brother, Werner Siemens,

then a young lieutenant of artillery in the Prussian service, in his endeavors to accomplish electro-gilding—the first impulse in this direction having been given by Professor C. Himley, then of Göttingen. After attaining some promising results, a spirit of enterprise came over me, so strong, that I tore myself away from the narrow circumstances surrounding me and landed at the East-end of London, with only a few pounds in my pocket and without friends, but with an ardent confidence of ultimate success within my breast. I expected to find some office in which inventions were examined, and rewarded if found meritorious; but no one could direct me to such a place. In walking along Finsbury pavement, I saw written up in large letters, so-and-so (I forget his name), ‘*Undertaker*,’* and the thought struck me that this must be the place I was in quest of. At any rate I thought that a person advertising himself as an undertaker would not refuse to look into my invention, with a view of obtaining for me the sought-for recognition or reward.

“On entering the place I soon convinced myself, however, that I had come decidedly too soon for the kind of enterprise then contemplated; and, finding myself confronted with the proprietor of the establishment, I covered my retreat by what he must have thought a very inadequate excuse. By dint of perseverance I found my way to the patent-office of Messrs. Poole & Carpmael, who received me kindly, and provided me with a letter of introduction to Mr. Elkington. Armed with this letter, I proceeded to Birmingham to plead my cause with him. In thinking back to that time, I wonder at the patience with which Mr. Elkington listened to what I had to say, being very young, and scarcely able to find English words to convey my meaning. After showing me what he was doing already in the way of electro-plating, Mr. Elkington sent me back to London in order to read some patents of his own, asking me to return if, after perusal, I still thought I could teach him anything. To my great disappointment, I found that the chemical solutions I had been using were actually mentioned in one of his patents, although in a manner that would hardly have sufficed to enable a third person to obtain practical results. On my return to Birmingham I frankly stated what I had found; and with this frankness I evidently gained the favor of Mr. Josiah Mason, who had just joined Mr. Elkington in business, and whose name as Sir Josiah Mason will ever be remembered for his munificent endowment of education. It was

* The literal translation of the German *Unternehmer*.

agreed that I should not be judged by the novelty of my invention, but by the results which I promised, namely, of being able to deposit with a smooth surface three pennyweights of silver upon a dish-cover; the crystalline structure of the deposit having heretofore been a source of difficulty. In this I succeeded; and I was able to return to my native country and my mechanical engineering a comparative Croesus. Notwithstanding the lapse of time," he said nearly forty years afterward, "my heart still beats quick each time I come back to the scene of this, the determining incident of my life."

After his return to Germany, he passed a year as a pupil in Count Stolberg's engine-works. While there, he perfected a steam-engine governor which had been suggested by his brother. With this invention, he returned to England in 1844, so that he might enjoy the security afforded by the English patent-law. He now concluded to remain in England, and was naturalized in 1850. Not long after he had taken up his permanent residence in England, he married the lovely and accomplished Scotch lady whose cordial hospitality it has been the good fortune of some of us to enjoy.

Now began that wonderful series of inventions and discoveries which followed one another with almost bewildering rapidity. The list of patents and contributions to technical journals which is attached to this memoir tells the story of mental work and ceaseless energy more perfectly than the most eloquent biographer could do it. Particular attention, however, should be drawn to what may properly be called his revolutionary discoveries, in the domain of heat and electricity.

"Already in 1846 he began the study of the economy of fuel, in the light of recent investigations respecting the true nature of heat."

. . . . "He read the treatises of Joule, Carnot, and Mayer, and proceeded to experiment on the principles thus brought to light. . . .

"On comparing the theoretic power of heat with the mechanical power given off by the heat applied to steam-engines and caloric engines generally, he saw there was a large margin for improvement. He at once determined to try to save or utilize some of the wasted heat; and conceived the idea of making a *regenerator* or accumulator for the purpose of retaining a limited quantity of heat, and capable of yielding it up again when required for the performance of any work. In 1847 he constructed an engine with a condenser provided with regenerators. The economy of fuel was considerable, but mechanical difficulties prevented success. He did not however abandon

the subject, for he eventually put engines into practical operation in England, France, and Germany, varying from five to forty horse-power."

Notwithstanding the great improvements which have been made in steam-engineering in the last decade, Sir William Siemens told the British Association in August, 1882, that "the best steam-engine does not yield in mechanical effect more than one-seventh part of the heat-energy residing in the fuel consumed. To obtain more advantageous primary conditions, we have to turn to the caloric or gas-engine. Before many years have elapsed, we may find in our factories and on board our ships engines with a fuel-consumption not exceeding one pound of coal per effective horse-power per hour, in which the *gas-producer* takes the place of the somewhat complex and dangerous steam-boiler. The advent of such an engine, and of the dynamo-machine, must mark a new era of material progress at least equal to that produced by the introduction of steam-power in the early part of our century."

Now that the Prophet has left us, who will undertake to fulfil the prophecy? There is no grander field for research than the one indicated by this master of investigation.

The temptation is great to follow up step by step the development of his genius; but we must resist it, and come to that part of his work which is of more direct interest to the members of the Institute.

The regenerative engine was evidently the forerunner of the regenerative gas-furnace. "In 1857, his brother Frederick suggested to him the employment of regenerators for the purpose of getting up a high degree of heat in furnaces, and he thenceforth labored to attain this result."

After many experiments and disappointments, he erected a regenerative-furnace at a glass-works in Birmingham, which proved a success.

The history of this period is so interesting that it will bear repeating at considerable length. It is well told by Mr. W. T. Jeans.

In 1862 Professor Tyndall lectured before the Royal Institution on the "Mechanical Theory of Heat," paying eloquent tribute to Mayer and Joule.

"A fortnight later, an account was given at the same institution of Mr. William Siemens's regenerative gas-furnace, *the greatest triumph in the practical application of the principles enunciated by Mayer and others*. That lecture was delivered by Michael Faraday,

the prince of pure experimentalists ; and it has the historic interest of being the last lecture he was able to deliver. The circumstances in which it was delivered were memorable. Some weeks previously, Siemens received the following letter from Faraday : ‘ I have just returned from Birmingham, where I saw at Chance’s works the application of your furnaces to glass-making. I was very much struck with the whole matter. As our managers want me to end the ‘ Friday evenings ’ at the Royal Institution after Easter, I have looked about for a thought, for I have none in myself. I think I should like to speak of the facts I saw at Chance’s, if you have no objection. If you assent, can you help me with any drawings, or models, or illustrations, either in the way of thoughts or experiments ? Do not say much about it out of doors as yet ; for my mind is not settled in what way, if you assent, I shall present the subject.’

“ Siemens readily assented, and spent two days at Birmingham in showing Faraday over the works where his furnaces were in operation. On the appointed Friday evening, June 20th, 1862, the venerable *savant* appeared before the Royal Institution for the last time, to explain the wonderful simplicity, power, and economy of the regenerative gas-furnace. In the course of his lecture, which lasted about an hour, and which he concluded by bidding his audience a pathetic farewell, he accidentally burned his notes ; and he was only able afterward to give the abstract of it that is published in the *Proceedings*.”

The almost universal adoption of the Siemens heating-furnace in iron and steel-works, and in operating the open-hearth process, is too well known to make it necessary for me to dwell upon the merits of either.

Through the courtesy of Messrs. Richmond and Potts, the agents of Messrs. Siemens in this country, I am enabled to furnish the following interesting facts about the adoption of the Siemens furnace in the United States.

The first Siemens heating furnace was started September 26th, 1867, at the works of the Nashua Iron Company, Nashua, N. H.

A small open-hearth steel-melting furnace, built at Trenton at the works of Cooper, Hewitt & Co., was started in December, 1868, but it has never been worked with any degree of regularity.

In January, 1870, an open-hearth steel-melting furnace was started up at the Bay State works in South Boston, and was the first furnace of that kind put regularly to work in this country.

The first crucible steel-melting furnace was built at the works of Anderson & Woods, Pittsburgh, and was started November 2d, 1867.

There have been built in this country : 165 Siemens furnaces for heating iron and steel ; 58 open-hearth furnaces ; 56 crucible-steel furnaces, and over 30 furnaces for sundry other purposes, such as glass-melting, zinc-smelting, puddling, etc.

It is strange that abroad the Siemens furnace is in use for the manufacture of *glass* to a greater extent than for any other purpose, and yet it is applied to that branch of manufacture in but few cases in this country. The annual capacity of the Siemens furnaces in use in this country may be stated as follows :

Heating-furnaces,		2,000,000 tons.
Open-hearth furnaces,		350,000 "
Crucible-furnaces,		70,000 "

It is safe to say that of the total production of wrought-iron and steel in the United States, fully one-third is heated in Siemens's furnaces, and practically all of the open-hearth steel and two-thirds of the crucible-steel is made in these furnaces. If we place the amount of iron and steel heated per annum by the Siemens furnaces at 1,500,000 tons, and consider the saving at \$2.50 per ton, we have an annual saving of \$3,750,000. The production of open-hearth steel in 1883 was about 2,000,000 tons ; and it is safe to estimate the saving in making this steel at \$20 per ton, over any other method of producing the *same quality* of product. Crucible-steel manufacturers readily accord a saving of \$10 per ton by using the Siemens furnace, and at least 60,000 tons were produced in 1883.

Mr. Jeans, in the *Journal of the Iron and Steel Institute*, says : " Until 1873 the total quantity of open-hearth steel produced in the United Kingdom was 77,500 tons. During the next two years this figure was not much improved upon ; but in 1876 the product had advanced to 128,000 tons ; in 1878 to 174,000 tons ; in 1880 to 251,000 tons ; and in 1882 to 436,000 tons."

The estimated quantity for 1883 is 500,000 tons. At the end of 1883 fully 370 open-hearth furnaces had been erected throughout the world, equal to an annual production of about 1,500,000 tons.

Siemens always talked of the ultimate success of his "direct process" with as much confidence as of any of his inventions. Had his life been prolonged, I have no doubt that he would have achieved success in this direction, and would have made the direct process a necessary adjunct to the open hearth.

A discussion of his triumphs in other branches of science as applied to the arts will not properly find a place in this communica-

tion. A glance, however, at the record attached, leads one to think that that work in which we are most interested, held but a subordinate place among his thoughts and deeds.

In 1876 Dr. and Mrs. Siemens paid a short visit to this country, and always after spoke with pleasure of the country, its resources and development, and the hospitality of its people.

"Sir William Siemens filled many positions of distinction, both public and private, and was the recipient of many honors. In addition to the Bessemer Gold Medal of the Iron and Steel Institute, presented to him in 1876, he received in 1874 the Albert Gold Medal of the Society of Arts, which also, as early as 1850, awarded him a gold medal for his regenerative condenser. In 1853 he received from the Institution of Civil Engineers, the Telford Medal for his paper 'On the Conversion of Heat into Mechanical effect;' and only a short time before his death the same institution conferred on him the Howard Quinquennial Prize. He also received prizemedals at the International Exhibitions of 1851, 1862, and 1867. Few men have filled within so short a time so many presidential chairs. He was president of the Institution of Mechanical Engineers (1872), of the Society of Telegraph Engineers and Electricians (1875), Iron and Steel Institute (1877), and of the British Association (1882); while in the latter year he was also elected to preside over the Council of the Society of Arts; and in 1881 he was elected a vice-president of the newly formed Society for the Promotion of Chemical Industry. He was besides, in 1862, made a fellow, and in 1869 a member, of the Council of the Royal Society. He was a D.C.L. of Oxford, and an LL.D. of Glasgow University, and, finally, in March, 1883, he received from Her Majesty the honor of knighthood."

Concerning my personal relations with him, this is not the place to speak at length. It is needless to say that I was thus laid under the deepest obligations of gratitude, as well as impressed with the most vivid sentiment of affection and esteem. In company with a worthier guest,—the brilliant and lamented Holley,—it was my privilege to learn, by personal and profitable experience, the hospitality of the home and the generosity of the heart of Charles William Siemens. In this respect—of lavish kindness to their professional colleagues (or, let me rather say, disciples)—Siemens and Holley were congenial spirits; and we may say of the former, as well as of the latter, that in his departure we have lost, not merely a leader, but also a friend.

APPENDIX I.

RECORDS OF THE WORK OF C. WILLIAM SIEMENS.
CHRONOLOGICALLY ARRANGED.

Year.	NAME, TITLE, Etc.	Mingler's Polytech- nisches Journal.		Telegraphic Journal. (Electrical Review).		The Electrician.		Journal of the Society of Telegraph Engi- neers and Electri- cians.		London Engineering.	Miscellaneous Publications.
		Vol.	P.	Vol.	P.	Vol.	P.	Vol.	P.		
1845	Differential Governor. Werner and C. William Siemens, (Illustrated).	98	81								
1846	Patented Improvements in Steam-Engines and especially in Steam Gov- ernors.	99	475								
1847	Anastatic Printing, by Siemens Brothers, London.	105	75								
1847	Process for Dissolving Kaolin for the Production of Artificial Stones. Werner and C. William Siemens.	106	448								
1848	Patented Improvements in Steam, and other Engines worked by Elastic Fluids.	108	152								
1849	Patented Improvements in Steam-Engines and in the Process of Evapora- ting Liquids.	112	394								
1851	Siemens Patent Regenerative Condenser.	122	402								
1852	New Regenerative Condenser for High and Low Pressure Engines (Illustrated).	123	249								Report of the Proceedings of the Inst. Mechanical Engineers.
1852	Patent for an Improved Means of Measuring Liquids.	126	70								
1852	The Expansion of Dry Steam, and the Total Heat of Steam. (Illustrated).	127	81								
1853	On the Conversion of Heat into Mechanical Effect.										
1853	On an Improved Governor for Steam-Engines.										Transactions, Inst. Civil Engineers.
1854	The Siemens Water Meter. (Illustrated).	131	243								Report of the Inst. of Mech. Eng.
1855	Improvements in Electric Telegraphs, Patented by William Siemens in England. (Illustrated).	138	176								
1855	The William Siemens Engine with Regenerative Steam. By F. Moigno.	138	241								
1855	The Regenerative Steam-Engine.										Mechanics Magazine, vol. 65, p. 55.
1856	Apparatus for the Simultaneous Dispatch of Telegraphic Messages in Opposite Directions on a Single Wire. Patented in London.	139	161								
1857	Efficiency of the Siemens Steam-Engine with Regenerated Steam.	143	463								
1857	New Design of Furnaces.	146	174								
1857	The Siemens Water Meter [see Vol. 131]. (Illustrated).	146	334								

1857	Improvements in Cooling and in Freezing Water and other bodies,	...	...	...	...	...	...	...	...	Report of Pat. Invent. (2), vol. 27, pp. 296-299.
1858	Heating-Furnace, in which the Heat of the Product of Combustion is largely Retained and Utilized. C. Wm. Siemens and F. Siemens. (Illustrated).	147	273	...	...	...	...	...	...	Journal of the Society of Arts. Committee Report to the Haldonadal Council, Oxford, 1860.
1858	On the Progress of the Electric Telegraph.	...	...	...	...	...	...	...	...	...
1860	The Cause of the Explosion at St. Mary's Church,	...	...	...	...	...	...	...	...	...
1860	Outline of the Principles and Practice Involved in Dealing with the Electrical Conditions of Submarine Electric Telegraphs. Dr. Werner and C. W. Siemens,	...	...	...	...	...	...	...	...	Brit. Ass., Oxford, 1860. German Trans. Zeitschr. d. deutsch-öesterr. Tel.-Vereins
1861	On a New Resistance Thermometer,	...	...	...	...	...	...	...	...	Report Brit. Ass. (2), p. 44. Phil. Mag. (2), vol. 21, p. 73.
1861	On the Bathometer, an Instrument to Indicate the Depth of the Sea on Board of Ship without Submerging a Line,	...	...	...	...	...	...	...	...	Report Brit. Ass. (2), p. 73. Civil Engineer, p. 308.
1861	On Fire and Railway Alarms,	...	...	...	...	...	...	...	...	Polyt. Centr.-Blatt, p. 1457.
1862	Regenerative Gas-Furnace. C. W. Siemens and F. Siemens in London. Their Adaptation for Glass Melting Furnaces. By C. Schinz. (Illustrated). See Dugler's Journal, Vol. 146,	156	270	...	...	...	...	...	...	...
1862	Electrical Instruments and Telegraphic Apparatus. Records of the International Exhibitions.	...	...	...	...	...	...	...	...	Practical Mechanics' Journal. Published, London, 1863.
1863	Patent Regenerative Gas-Furnaces. C. W. Siemens and F. Siemens.	...	...	...	...	...	...	...	...	...
1864	The Magneto-Electric Type-Writer of Siemens & Halske, in Berlin. Report by C. Wm. Siemens on the Electric Instruments and Telegraphic Apparatus at the International Exhibition in London, 1862. (Illustrated).	171	48	...	...	...	...	...	...	...
1864	The Electric Conductivity of Gutta Percha and India Rubber under various Pressures,	171	231	...	...	...	...	...	...	Cosmos, vol. 23, p. 354. Philosophical Transactions.
1865	On Uniform Rotation.	180	409	...	...	...	...	...	...	Brig. Zeitschr. d. deutsch-öesterr. Tel.-Ver., vol. 14, p. 76; and Phil. Mag., vol. 34, p. 270.
1867	Governors for Small and Large Engines. (Illustrated).	...	...	...	...	...	...	...	...	Report Brit. Ass. (2); p. 14. Monies (2), vol. 21, pp. 10-21.
1867	On a Measurer of Resistance,	...	...	...	...	...	...	...	...	...
1867	The Electric Illumination of Buoys,	...	...	...	...	...	...	...	...	...
1867	Discours sur Mécanique,	...	...	...	...	...	...	...	...	...
1868	The Machinery used in Laying a Cable under the Mediterranean. (Illustrated).	187	24	...	...	...	...	...	...	Lecturo before the Chemical Society. Paper before the Brit. Ass. at Woolwich.
1868	A New Instrument for the Practical Measurement of Electric Resistance in Wires. (Illustrated).	187	303	...	...	...	...	...	...	...
1868	The Manufacture of Cast Steel direct from the Ore, by means of Regenerative Gas-Furnaces. (Illustrated).	189	227	...	...	...	...	...	...	...
1868	The Process of Fuddling Iron,	190	203	...	...	...	...	...	...	...
1869	New Process for the Manufacture of Cast Steel by Means of Regenerative Gas-Furnaces. (Illustrated).	193	213	...	...	...	...	...	...	...
1869	Electric Balance Thermometer for Submarine Thermometric Observations,	198	516	...	...	...	...	...	...	Mechanics' Magazine, May, 1869.

APPENDIX I.—Continued.

Year.	NAME, TITLE, Etc.	Dingler's Polytech- nisches Journal.	Telegraphic Journal. (Electrical Review).	The Electrician.	Journal of the Society of Telegraph Engi- neers and Electri- cians.	London Engineering.	Miscellaneous Publications.
		Vol.	P. Vol.	P. Vol.	Vol.	Vol.	P.
1870	Siemens' Pyrometer.	198	258				
1870	Pyrometer of C. William Siemens (refer to preceding article). Discussed by C. Schütz.	198	394				Polyt. Centr. Blatt., pp. 1413-17.
1871	Note on the Blast Pipe.	201	41				Report British Association.
1871	Electric Pyrometer.	202	10				Process lines, Inst. Mech. Eng., Bir- mingham.
1871	On the Steam Blast.	203	521				Institute of Civil Engineers, vol. 3.
1872	Siemens' System of Blowing Engine.	206	3				
1872	The Steam-Jet Exhauster, and its Application.	206	182				
1872	On Pneumatic Despatch Tubes; the Circuit System.	207	265				
1872	Siemens' Pneumatic System of Forwarding Dispatches. Note from the London Exhibition, by J. Zeman.	206	182				Inaugural Address, Society of Tel. Engineers, Nature, vol. 6, p. 282.
1872	Siemens' Combined Roasting and Shaft Furnace. (Illustrated).	207	265				Address before the Royal Institute.
1872	The Electric Telegraph; its Improvements and Capabilities.	207	265				
1872	Measuring Temperature by Electricity.	207	265				
1873	Iron Telegraph Poles.	207	265				
1873	Application of the Steam-Jet for the Aspiration or Compression of Gases.	207	265				
1873	On the Manufacture of Iron and Steel by Direct Process.	207	265				Paper at the April Meeting of the I. and S. Inst. Published in Ger- man by Springer, Berlin.
1873	Siemens' Rotator for the Production of Iron and Steel direct from the Ores. (Illustrated.) Note from the Vienna Exhibition of 1873, by J. Zeman.	209	1				Report British Association. German Traus., Jul. Springer, Berlin.
1873	On Fuel; a Lecture to the Operative Classes at Bradford, Sept. 1873.	209	1				
1873	The Electric Pyrometer. (Illustrated).	209	419				
1874	On the Dependence of Electrical Resistance on Temperature.	209	419	1	293		
1875	C. Wm. Siemens' Electric Pyrometer. (Illustrated).	217	291				Transactions of the Society of Tele- graph Engineers.
1875	Electric Resistance Thermometer and Pyrometer.	217	291				
1875	A Copper-Steel Wire for Telegraphic Purposes, from the Factory of Siemens Brothers in Woolwich.	217	334				

APPENDIX II.

ENGLISH PATENTS* GRANTED TO THE MESSRS. SIEMENS.

The initials in the first column of the table stand for: C. W. S., Charles William Siemens; E. W. S., Ernest Werner Siemens; C. H. S., Charles Henry Siemens; F. S., Frederick Siemens; G. S., George Siemens; L. S., Louis Siemens; v. H. A., von Hefner Alteneck. The S. has been omitted where two names occur in one line.

PATENTEE.	No.	DATE.	SUBJECT.
C. W. S.	11021	24. 12. 45.	Regulating power and velocity of steam engines.
C. W. S.	12006	22. 12. 47.	Engines to be worked by steam or other fluids.
C. W. S.	12531	20. 3. 49.	do. do. do. do.
E. W. S.	13062	23. 4. 50.	Electric telegraphs.
C. W. S.	14060	15. 4. 52.	Fluid meter.
C. W. S.	326	9. 10. 52.	Steam engines.
C. W. S.	712	23. 3. 53.	Rotatory fluid meter.
C. W. S.	459	25. 2. 54.	Electric telegraphs.
C. W. S.	2366	8. 11. 54.	do.
C. W. S.	1105	16. 5. 55.	Apparatus for freezing water.
C. W. S.	2514	7. 11. 55.	Evaporation of brine.
C. W. S.	1363	9. 6. 56.	Engines with superheated steam.
C. W. S.	2107	10. 9. 56.	Electric telegraphs.
C. W. S.	2824	29. 11. 56.	Fluid meters.
F. S.	2861	2. 12. 56.	Furnaces.
C. W. S.	1320	11. 5. 57.	Furnaces.
C. W. S.	2064	29. 7. 57.	Apparatus for making ice
C. W. S.	1457	28. 6. 58.	Cleansing tidal rivers.
C. W. S.	2074	13. 9. 58.	Refrigerators.
C. W. & E. W.	2180	30. 9. 58.	Electric telegraphs.
C. W. S.	87	11. 1. 59.	Supports for telegraph wires.
C. W. & E. W.	512	25. 2. 59.	Electric telegraphs.
C. W. & E. W.	2503	3. 11. 59.	Insulating electric telegraph conductors.
C. W. S.	519	25. 2. 60.	Electric telegraph cables.
C. W. S.	2074	28. 8. 60.	Steam engines.
C. W. S.	2982	5. 12. 60.	Fluid meters.
C. W. & F.	167	22. 1. 61.	Furnaces.
C. W. & E. W.	281	31. 8. 61.	Electric telegraphs.
C. W. S.	2805	8. 11. 61.	Armored war vessel.
C. W. & E. W.	59	9. 1. 62.	Insulating electric telegraphs.
C. W. & E. W.	1540	22. 5. 62.	Electric telegraph apparatus.
C. W. S.	2143	28. 7. 62.	Gas engines.
C. W. S.	464	20. 2. 63.	Insulating electric telegraphs.
C. W. & F.	972	18. 4. 63.	Furnaces.
C. W. & E. W.	2826	13. 11. 63.	Submarine cables.
C. W. S.	1447	10. 6. 64.	Manufacture of glass.
C. W. S.	3018	3. 12. 64.	do. do.
C. W. & E. W.	3260	31. 12. 64.	Apparatus for motive power.
C. W. S.	1230	2. 5. 65.	Regulating velocity of machinery.
C. W. S.	2391	19. 9. 65.	Separating dust in iron blast furnaces.
C. W. S.	671	5. 3. 66.	Zinc furnaces.
C. W. S.	2413	20. 9. 66.	Ore-smelting furnaces.
C. W. & E. W.	3090	24. 11. 66.	Pneumatic despatch.
C. W. & E. W.	261	31. 1. 67.	Methods of developing powerful electric currents.
C. W. & E. W.	631	7. 3. 67.	Fluid meters.
C. W. & E. W.	1532	23. 5. 67.	Pneumatic despatch.
C. W. S.	2395	21. 8. 67.	Ore-smelting furnaces.
C. W. S.	1172	7. 4. 68.	Gas regenerative furnaces.
C. W. & E. W.	1253	17. 4. 68.	Electric measurements of distances.
C. W. S.	1462	5. 5. 68.	Steel furnaces.
C. W. S.	1892	10. 6. 68.	do.
C. W. S.	3501	18. 11. 68.	Fastening telegraph wires.
C. W. S.	3569	24. 11. 68.	Steel furnaces.
C. W. S.	1575	21. 5. 69.	Smelting furnaces.
C. W. S.	2988	14. 10. 69.	Steel furnaces.
C. W. S.	34	5. 1. 70.	Regenerative hot-blast furnaces.
C. W. S.	594	28. 2. 70.	Treatment of iron ores.
C. W. & F.	1513	25. 5. 70.	Regenerative gas furnaces.

* It was obviously not necessary to give the American, German, or other patents, which were in all cases, I believe, for inventions substantially covered by the English patents.

PATENTEE.	No.	DATE.	SUBJECT.
C. W. S.	3134	30. 11. 70.	Treatment of iron ores.
C. W. S.	3255		Improvement in means for exhausting receivers.
C. W. S.	292	2. 2. 71.	Cast steel.
C. W. S.	1959	26. 7. 71.	Smelting iron ores.
C. W. S.	3077	15. 11. 71.	Treating iron ores.
C. W. S.	1998		Electric telegraphs.
C. H. S.	1473	15. 5. 72.	Telegraphs.
E. W. S.	1919	25. 6. 72.	Obtaining and applying electric currents.
F. S.	2152	18. 7. 72.	Glass furnaces.
C. W. S.	2861	28. 9. 72.	Iron and steel furnaces.
C. H. & E. W.	2923	3. 10. 72.	Telegraphs.
C. W. & F.	3478	21. 11. 72.	Glass furnaces.
C. W. S.	3642	3. 12. 72.	Smelting furnaces.
E. W. & v. H. A.	2006	5. 6. 73.	Electric light.
E. W. & v. H. A.	2225	27. 6. 73.	Electric telegraphs.
F. S.	2246	28. 6. 73.	Caloric engines.
G. & de Groussilliers.	2838	28. 8. 73.	Soda and potash.
C. W. S.	4075	11. 12. 73.	Iron and steel manufacture.
C. W. S.	428		Treating puddled balls.
E. W. S.	1307	16. 4. 74.	Telegraphic signals.
C. W. & Stein.	3457		Calcining kilns.
C. W. S.	43	5. 1. 75.	Furnaces.
C. W. S.	1551	28. 4. 75.	Glass furnaces.
F. S.	1637	3. 5. 75.	Hardening glass.
C. W. S.	1540	20. 4. 76.	Iron and steel to resist shock.
F. & Mason.	1657	28. 4. 76.	Tempering glass.
F. S.	2097	20. 5. 76.	Ornamenting toughened glass.
C. W. S.	3370	5. 9. 76.	Iron and steel.
C. W. S.	3714	22. 9. 76.	Iron and steel furnaces.
F. & Heese.	3904	10. 10. 76.	Pottery kilns.
C. H. & E. W.	4685	10. 12. 76.	Telephones.
F. S.	4780	11. 12. 76.	Glass.
C. W. S.	4793	17. 12. 76.	Armor-plating.
C. W. S.	251	19. 1. 77.	Electric telegraph conductors.
C. W. S.	700	20. 2. 77.	Regenerative gas furnace.
C. H. S.	1871	14. 5. 77.	Recording electric telegraph signals.
C. W. S.	2281	7. 6. 77.	Electric lamps.
E. W. & v. H. A.	3134	8. 8. 77.	Reproducing electricity for illumination.
C. H. S.	4685	10. 12. 77.	Telephones.
C. W. S.	251	19. 1. 78.	Electric telegraph conductors.
C. W. S.	700	20. 2. 78.	Regenerative gas furnace.
C. W. S.	2281	7. 6. 78.	Distributing electric currents to lamps.
C. H. & E. W.	2527	25. 6. 78.	Telephones.
C. H. & E. W. & v. H. A.	3134	8. 8. 78.	Producing and regulating electric currents for lamps.
C. W. S.	3315	22. 8. 78.	Electric lighting.
C. W. S.	4208	22. 10. 78.	Electric illumination.
C. W. & v. H. A.	4949	4. 12. 78.	Electric lamps.
C. W. S.	694	20. 2. 79.	Ordnance.
C. W. & F.	1118	20. 3. 79.	Annealing glass.
C. W. S.	2110	27. 5. 79.	Light and heat by electricity.
L. S. & Justushofen.	2199	3. 6. 79.	Lighting by electricity.
F. S.	2231	5. 6. 79.	Lamps and burners.
C. W. & v. H. A.	2652	1. 7. 79.	Electric lamps.
C. W. S.	2775	8. 7. 79.	Tension bars.
F. S.	3555	4. 9. 79.	Burners.
C. W. S.	4534	6. 11. 79.	Dynamo machines.
C. W. & F.	4763	22. 11. 79.	Moulding glass.
F. S.	5135	15. 12. 79.	Moulding and annealing glass.
C. W. S.	5150	16. 12. 79.	Iron and steel manufacture.
C. H. & E. W.	583	10. 2. 80.	Conveying persons by electro-motive power.
F. S.	1561	16. 4. 80.	Lamps.
C. W. S.	3374	19. 8. 80.	Gas furnaces.
C. W. S.	4614	10. 11. 80.	Electric lamps.
C. W. S.	4683	13. 11. 80.	Gas lamps.
F. S.	5172	10. 12. 80.	Lamps.
C. W. & Boothby.	696	17. 2. 81.	Electric brakes.
C. W. S.	883	1. 3. 81.	Iron and steel manufacture.
C. W. & Halske.	1447	1. 4. 81.	Dynamo machines.
C. W. S.	2504	9. 6. 81.	Gas motors.
F. S.	2638	17. 6. 81.	Lamps.
C. W. S.	2651	17. 6. 81.	Steel manufacture.
C. W. S.	3792	31. 8. 81.	Steel manufacture.
C. W. S.	5350	7. 12. 81.	Gas engines.
C. W. & F. J.	231	17. 1. 82.	Telephone conductors.
C. W. & E. W.	760	16. 2. 82.	Dynamo-electric machine.



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